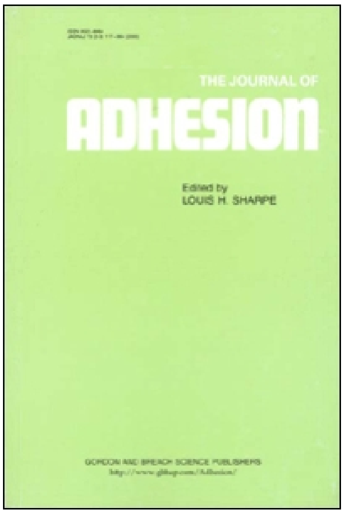

The Journal of Adhesion

Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713453635

The Methods of Measuring Tackiness of Pressure Sensitive Adhesive Tapes

K. Kamagata; T. Saito; M. Toyama

To cite this Article Kamagata, K. , Saito, T. and Toyama, M.(1970) 'The Methods of Measuring Tackiness of Pressure Sensitive Adhesive Tapes', The Journal of Adhesion, 2: 4, 279 — 291

To link to this Article: DOI: 10.1080/0021846708544601

URL: http://dx.doi.org/10.1080/0021846708544601

*The Methods of Measuring Tackiness of Pressure Sensitive Adhesive Tapes

K. KAMAGATA, T. SAITO and M. TOYAMA
Research Dept. Nichiban Co. Ltd.
36-23, Nukui-1, Nerimaku, Tokyo, Japan

ABSTRACT

Tackiness of adhesive tapes has been measured by many investigators using many different methods. Therefore, the tackiness of the same sample may vary widely, depending on the test method used. In general, the tackiness is measured by the finger test. Since the finger test involves many complicated factors such as psychological factors and individual differences, etc., it is difficult to quantitize the results of the finger test. The authors measured the tackiness of commercial plastic film adhesive tapes and cloth adhesive tapes by the use of several tack test methods. The results were compared with those obtained from the finger test. It was found that the rolling ball tack tester with a sine curved surface of $y = 86.7 \cos(\pi/300 \times x) + 86.7$ and an average slope of 30° gave results closest to those obtained by the finger test.

1. INTRODUCTION

THE MAIN FUNCTION of a pressure sensitive adhesive tape is its tackiness. The mechanism of tackiness can be classified into two groups; the wetting against the solid body to be taped, and the resistance against the detachment of the tape from the taped solid body. In general, the latter mechanism is measured to estimate the tackiness of adhesive tapes. The method for this measurement varies widely, depending on each investigator.[1-4] F. H. Wetzel[1] and Kamagata *et al.*[2] pressed a sample tape against a brass cylindrical column installed on an Instron constant-speed tensile meter for a constant period of time with constant pressure and measured the force needed to detach the tape from the brass column. This value was used to evaluate the tackiness of the tape.

F. H. Hammond Jr.[3] used a probe tack tester, a somewhat simplified form of the apparatus mentioned above, to measure the tackiness of the tape.

N. Brunt[4] designed a balance type tack meter. In this test method the sample was spread over a glass plate and a ball was adhered to the plate. The force needed to pull the ball off the plate was measured and was used to evaluate the tackiness of the sample.

Recently, Toyama[5] classified the tackiness into primary tack, secondary tack and equilibrium tack. The primary tack is the surface chemical wetting in relation to the surface energy of the material being taped. The secondary tack is the rheological wetting. The equilibrium tack is the rheological

*Translated and reprinted from *J. Adh. Soc. Japan*, 5, No. 6, 364, (1969) by kind permission of the Society.

wetting of the surface accompanied by the change in the internal phase of the adhesive agent due to the presence of the material being adhered. The tackiness has frequently been compared with the results of the finger test. Two factors are involved in the finger test; the factor involving the spreading of wetting after the finger has been in contact with the sample and the factor concerning the adhesive resistance of the sample while the finger is being pulled off the sample. If the former factor is considered to be the main factor, the result has to be discussed on the base of the primary tack, and if the latter is considered to be the main factor, discussion of the test results should be based on the secondary tack. Therefore, the contact time is important in the finger test. As mentioned before, since the tackiness has frequently been compared with the results of the finger test, an apparatus which can measure the above mentioned two factors simultaneously is desirable. In this study, the tackiness of several commercial adhesive tapes was measured by several methods and the results were compared with those obtained by the finger test.

2. APPARATUS, METHODS OF MEASUREMENT AND SAMPLES.

2.1 Rolling Ball Tack Tester

J. Dow[6] placed an adhesive tape with constant length on a surface with 30 degree slope and rolled 32 steel balls of different sizes (diameter 1/32 to 1 inch) along the slope from a constant height. The ball with the largest diameter which could be stopped on the adhesive tape was used to measure the tackiness of the tape. Other methods used are the Douglas rolling ball stick tester developed by the Douglas Aircraft Co. and PSTC-18, the rolling ball tack tester of the Pressure Sensitive Tape Council. We have modified the testers mentioned above and designed the tack tester shown in Fig. 1. The curved surface is a sine curve which can be expressed by the equation (1) below and has an average slope of 30 degrees.

$$y = 86.7 \cos(\pi/300 \times x) + 86.7 \tag{1}$$

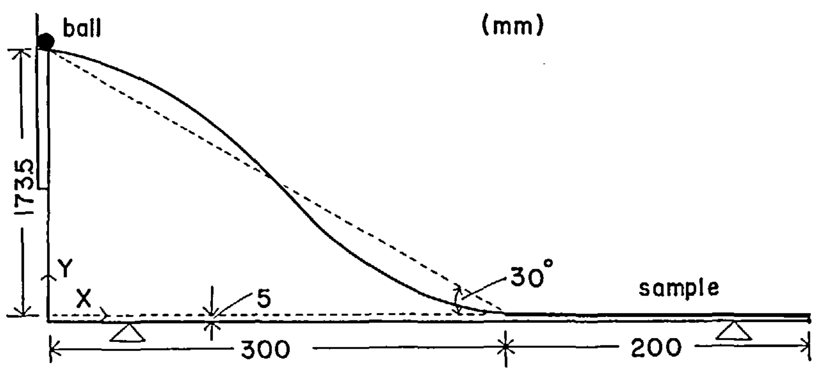

Figure 1. Schematic diagram of rolling ball tack tester.

The common characteristic of all rolling ball tack testers is that this method can measure the resistance against detachment after a short time period of contact with sample adhesive tapes. In addition to this characteristic, the tester designed by the authors showed more advantages in that the steel ball would not slide down the curved surface but would undergo smooth rolling. The steel ball would also move smoothly from the curved surface onto the sample surface.

For measurement, a steel ball is placed gently on the top of the tester to give the ball a constant potential energy. The plate is then pressed to let the ball roll down the curved surface. The distance between the initial contact point of the ball on the surface of the sample adhesive tape to the point of arrival of the ball is measured. The longer the arrival length of the rolling ball the lower the tackiness of the adhesive tape. The rolling of the ball on the curved surface and the sample surface is photographed by the use of a Hitachi high speed camera.

2.2 Ball Tack Tester

The attachment as shown in Fig. 2 (A) was installed on a TOM30 Type universal tensile tester manufactured by Shinko Communication Industries, Inc. A sample tape was fixed on the movable cross head with the adhesive surface facing up. The movable cross head was then moved upward at a constant speed to make contact with the steel ball. The cross head was then moved downward at a constant speed. A force-strain curve as shown in Fig. 2 (B) was then prepared. The area under the curve ,h, was measured and was used to calculate the ball tack energy. The tack force was obtained from the maximum force ,i, in the curve. These two values were used to evaluate the tackiness of the sample tape.

The weight of the ball itself was used as the contact pressure ,g. Contact time was 2.3-3.0 sec. and the speed of pulling the ball was 30 mm/min.

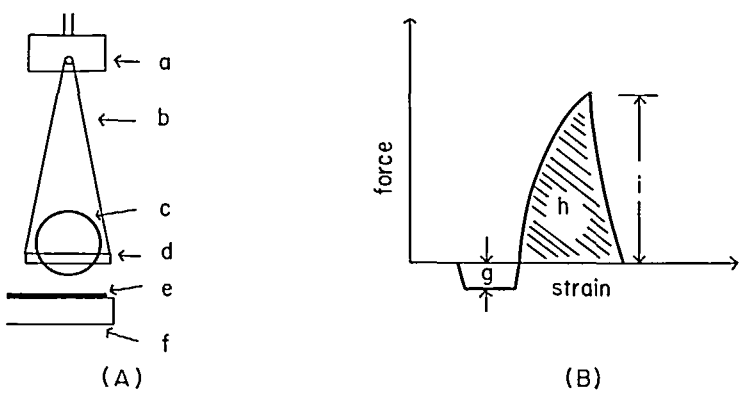

Figure 2. Measuring assembly of ball tack tester attached to the tensile tester (A) and force-strain relation (B); a: fixed cross head, b: silk yarn, c: ball, d: ring, e: sample, f: movable cross head, g: contact pressure, h: ball tack energy, i: ball tack.

2.3 Self Pressure Tack Tester

Several adhesive tapes (25 mm wide and 300 mm long) were layered to make a 10 mm thick ring with the adhesive surface facing outward. A glass rod was installed on the fixed cross head of a tensile tester identical to that used in the ball tack tester. The sample ring was then hung on the glass rod as shown in Fig. 3 (A). The movable cross head was moved upward to let the sample ring make contact with the steel panel fixed on the movable cross head for a constant period of time, Fig. 3 (B). The movable cross head was then moved downward and the force required to detach the sample from the panel was determined, Fig. 3 (C). The speed of contact and detachment was 300 mm/min.

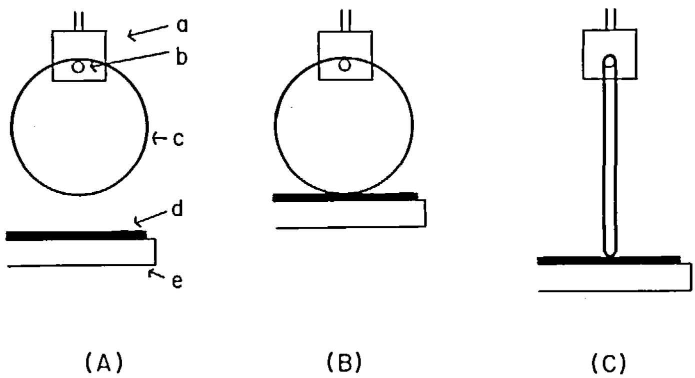

Figure 3. Schematic diagram of measuring method for self pressure tack; (A) before the contact, (B) maximum contact, (C) before the release of sample from panel; a: fixed cross head, b: glass bar, c: sample, d: steel panel, e: movable cross head.

2.4 Probe Tack Tester

The tester manufactured by the Kendall Company was used. Its structure is shown in Fig. 4. This tester has been used by Hammond for studying the tackiness of adhesive tapes[3]. A sample tape was fixed on the sample support ring W with its adhesive surface facing downward and was placed on the electric contact E. The carrier C was moved downward at a constant speed to let the adhesive surface of the sample make contact with the stainless steel probe P for a constant period of time. C was then moved upward at a constant speed and the force needed to detach P from the adhesive surface of the sample was measured by the use of the gauge G. The desired contact time can be set by turning the knob on the timer TC to the appropriate position. Ten different contact times ranging from 0.1 second to 100 seconds can be selected. The speed of detachment of the sample can be determined by the use

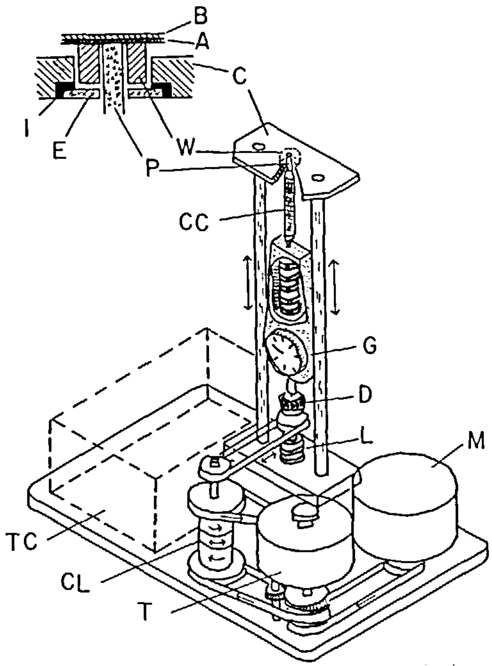

Figure 4. Schematic diagram of probe tack tester; B: backing, A: adhesive, W: weight, P: probe, C: carrier, I: Insulation, E: electrical contacts, CC: probe holder, G: gage, D: dashpot, L: lead screw, CL: clutches, T: transmission, M: motor, TC: time and controls.

of the transmission T. Ten different speeds ranging from 0.01 cm/sec to 10 cm/sec can be selected. The diameter of the probe used in our study was 0.5 cm. The contact time was 1 second and the speed of detachment was 1 cm/sec.

2.4 Finger Test (1)

In the tests described so far, the materials used to adhere to the tape were balls, plates or cylindrical columns.. A thumb is generally used in the finger test for tackiness examination of adhesive tape and its shape is rather complicated. In order to express the results of the finger test in numerical values, the attachment shown in Fig. 5 (A) was designed. This attachment was installed on the universal tensile tester described before. A sample tape was fixed on the sample supporting platform with the adhesive surface facing up. A thumb wiped clean with ether and alcohol was pressed on the sample and was pulled off immediately. The peak on the left side of the chart shown in Fig. 5 (B) was caused by the contact pressure. The measurement was carried out with this contact pressure being kept constant. The area of the diagram on the right side of the contact pressure peak was measured and this value was used to estimate the tackiness. It can be said that the higher the curve the stronger the adhesive agent and the wider the curve, the stickier the adhesive agent.

In all cases, the measurements were carried out at 21 ± 1°C.

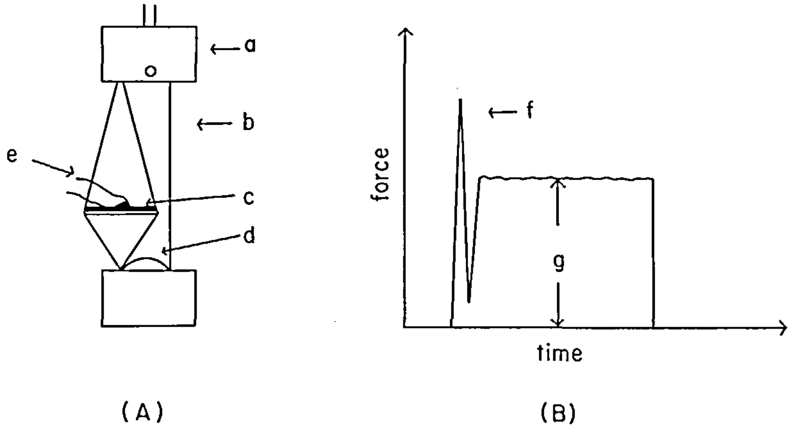

Figure 5. Measuring assembly of finger tester attached to the tensile tester (A) and force-time relation (B): a: fixed cross head, b: silk yarn, c: sample, d: pulley, e: finger, f: contact pressure, g: finger tack.

2.6 Finger Test (2)

Twenty-one experienced and inexperienced males and females were selected. Four types of cloth adhesive tapes were given to them to grade the samples according to their feeling of adhesiveness. The tape with the highest feeling of adhesiveness was given 4 points and that with the least adhesiveness 1 point. The points were then summed up and were used to determine the tackiness of the samples.

2.7 Samples

Seven kinds of adhesive tapes were used in this study. They were four kinds of commercial cloth adhesive tapes used for packaging (Expressed as A,B,C, and D), commercial cellophane adhesive tape (denoted as E), polyester adhesive tape, (denoted as F), and non-plasticized PVC adhesive tape (denoted as G).

Staple fibers treated with polyethylene, etc. were used as the base material for the cloth adhesive tapes.

3. RESULTS AND DISCUSSION

3.1 Rolling ball tack

The rolling state of a ball (15.9 mm diameter) on the curved surface and the adhesive surface of the rolling ball tack tester shown in Fig. 1 was photographed by the use of a Hitachi high speed camera. From the picture of the ball rolling on the adhesive surface, the positions of the ball at 1/100 second intervals were plotted on a graph and from the distance between two points,

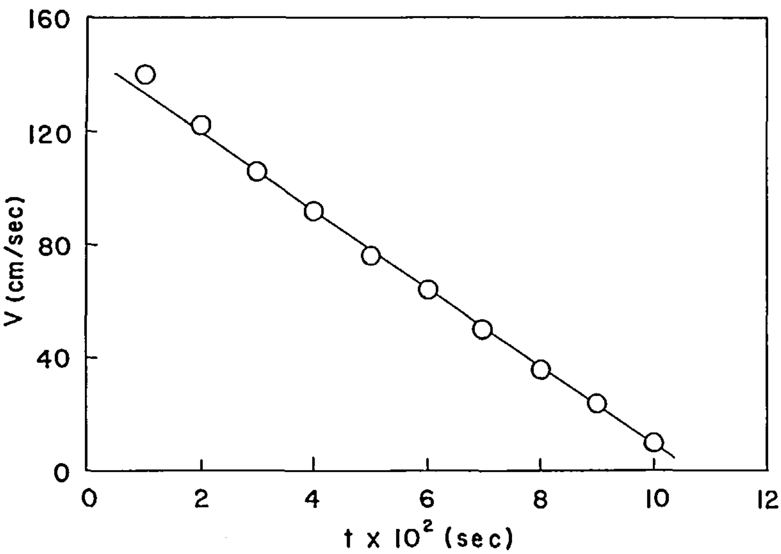

Figure 6. Relationship between the time and the velocity of rolling ball.

the speed of the rolling ball was determined. Fig. 6 shows a plot of the speed V against time elapsed. The velocity of the ball at the time of contact with the sample was found to be $V_{t=0} = 161 \pm 10$ cm/sec by the extrapolation of the curve. This value can also be calculated theoretically be the use of the equations (2), (3) and (4)

$$\frac{1}{2}mV^2 + Iw^2 = mgh \tag{2}$$

$$I = \frac{2}{5}mr^2 \tag{3}$$

$$V = rw \tag{4}$$

where m is the mass of the ball, V is the velocity, I the moment of inertia, ω the angular velocity of the ball, g acceleration of gravity, h height, and r the radius of the ball. From these equations, $V_{t=0} = 156$ cm/sec was obtained, which agrees well with the experimental value. The change with time of the velocity of the ball on the adhesive surface dV/dt can be correlated to the density of the dispersion energy—dE/dl as shown in the equation (5)

$$-\frac{dE}{dl} = -\frac{d(\frac{1}{2}mV^2)}{Vdt} = -\frac{m\,2\,VdV}{2\,Vdt} = -m\frac{dV}{dt} \tag{5}$$

Since dV/dt as shown in Fig. 6 is almost constant, the density of the dispersion energy is also roughly constant. Therefore, by dividing the potential energy given to the ball by the rolling distance of the ball, one can obtain the density of the dispersion energy. The value for the cellophane adhesive tape was found to be 1.4×10^5 erg/cm^2 which agrees very well with the value of 3.2×10^5 erg/cm^2 obtained by the 180 degree detachment test on the same sample.

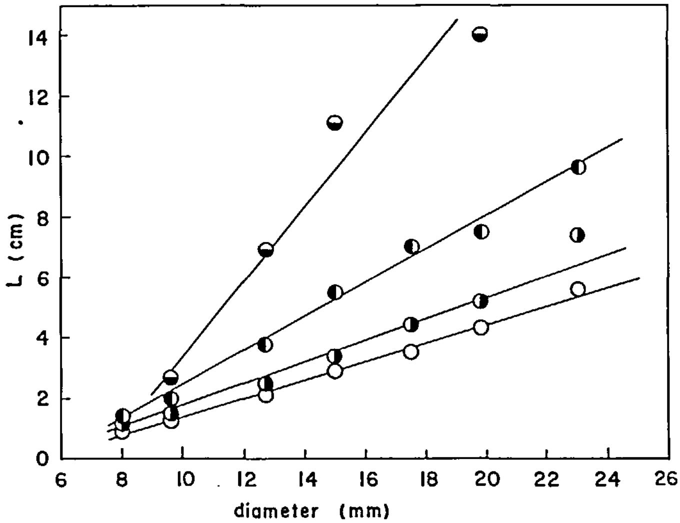

Figure 7. Relationship the diameter of ball and the arrival length of rolling ball; sample A: O, sample B: ◑, sample C: ◐, sample D: ⊖

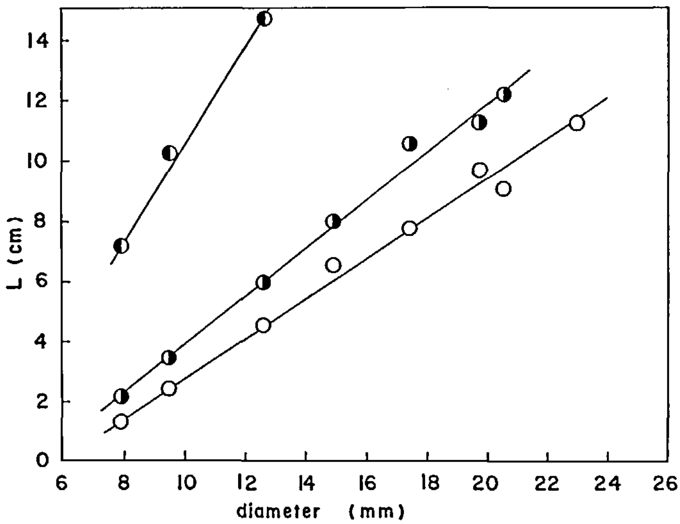

Figure 8. Relationship the diameter of ball and the arrival length of rolling ball; sample E; O, sample F: ◑, sample G: ◐.

Fig. 7 and Fig. 8 show the relationship between the diameter of the balls and the arrival length of the rolling balls for various adhesive tapes studied. When the diameter of the ball is increased, the measured values tend to fall into one point, indicating the accuracy of the values obtained by this tester.

In Fig. 7, A has the shortest arrival length and the smallest slope, i.e., A has the highest tackiness. The reciprocal of the arrival length of the rolling ball was used to express the tackiness.

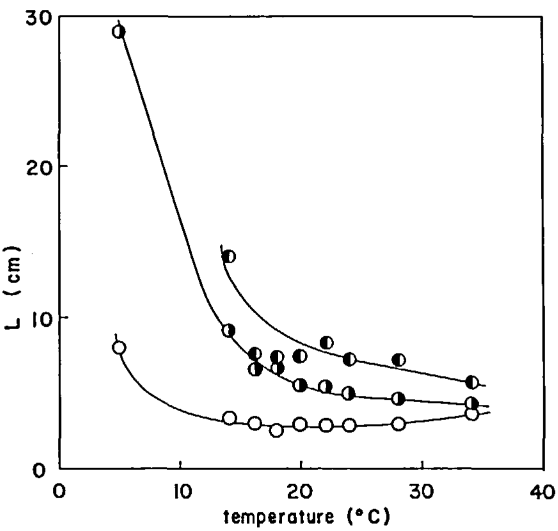

Figure 9. Dependence of arrival length of rolling ball on the temperature; sample A: ○, sample B: ◐, sample C: ◑.

Fig. 9 shows the results obtained with adhesive tapes A, B, and C tested in the temperature range of 5°C to 34°C. For the tape A, almost no temperature dependency could be noted at temperatures between 15°C to 30°C. Below 15°C or above 30°C, the arrival length of the rolling ball tended to be elongated, i.e., the tackiness decreased. This type of adhesive tape is known to show the highest tackiness at room temperature, according to the finger test. Therefore, the result of the rolling ball tack test agrees with that of the finger test.

3.2 Ball Tack

In the rolling ball tack test, a ball is rolled on the adhesive surface of a sample tape, and the reciprocal of the arrival length of the rolling ball is used to express the tackiness. In this case, the contact pressure is the weight of the ball itself. The contact pressure in the ball tack tester is also the weight of the ball itself, but the adhesive resistance encountered in the pulling of the ball at right angles to the adhesive surface of the sample is determined and is used to evaluate the tackiness of the sample. The relationship between the diameter of the ball and the ball tack energy is shown in Fig. 10 and Fig. 11. The ball tack energy increases with increasing ball diameter in the 1st or 2nd order fashion.

In Fig. 10, sample A exhibits the highest tackiness and B the lowest. The ball tack energy was used to express the ball tack value.

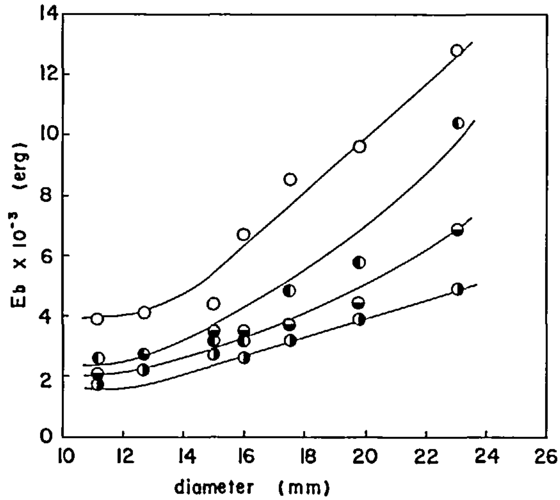

Figure 10. Relationship between the diameter of ball and the ball tack energy; sample A: ○, sample B: ◐, sample C: ◑, sample D: ⊖.

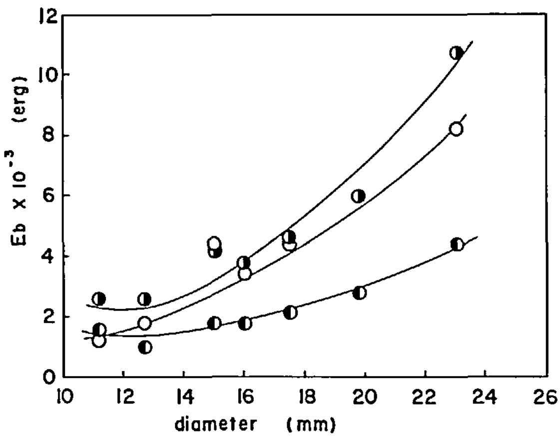

Figure 11. Relationship between the diameter of ball and the ball tack energy; sample E: ○, sample F: ◑, sample G: ◐.

3.3 Self Pressure Tack

The maximum force obtained in the force-strain curve was used as the self pressure tack. Table 1 shows the test results. In spite of the fact that base materials and adhesive agents used in all seven types of adhesive tapes studied are different, the values obtained were almost the same. Even the results obtained by the finger test for each sample show a significant difference. Therefore, this test method probably can only measure the wetting of the surface of the adhesive tape. The effect of base material and thickness of the adhesive layer cannot be determined by this test method.

Table 1. Self Pressure Tack of Commercial Pressure Sensitive Adhesive Tapes

Samples		*Self pressure tack. g/25mm*
Cloth adhesive tape	(A)	950
Cloth adhesive tape	(B)	1020
Cloth adhesive tape	(C)	1080
Cloth adhesive tape	(D)	1030
Cellophane adhesive tape	(E)	1040
Polyester adhesive tape	(F)	950
Non-Plasticized PVC adhesive tape	(G)	840

Table 2. Probe Tack of Commercial Pressure Sensitive Adhesive Tapes

Samples		*Probe tack g/cm2*
Cloth adhesive tape	(A)	2140
Cloth adhesive tape	(B)	2240
Cloth adhesive tape	(C)	2500
Cloth adhesive tape	(D)	1730
Cellophane adhesive tape	(E)	3420
Polyester adhesive tape	(F)	3360
Non-Plasticized PVC adhesive tape	(G)	3820

3.4 Probe Tack

It has been reported that the test values obtained by the probe tack tester are dependent on the contact time between the sample and the probe and also on the velocity of detachment.[2,3] In our study, the contact time was 1 second and the velocity of detachment was 1 cm/sec. Table 2 summarizes the test results. It is seen that the values of probe tack for each sample vary considerably, as compared with those of self pressure tack shown in Table 1. The value of the probe tack increases as the hardness of the base material of the adhesive tape increases.

It is known that the content of additive in the adhesive agent is related to the tackiness of the adhesive agent.[1,3,8,9] When the content of additive (horizontal axis) is plotted against the tackiness (vertical axis), a curve with a maximum point can be obtained. The rolling ball tack and the probe tack of the same sample with different resin concentration were measured and the results are shown in Fig. 12. Two different maximum values are obtained. These results indicate that even the widely used test methods for tackiness, i.e., the rolling back tack and probe tack tests, still measure the tackiness from different angles and give different results.

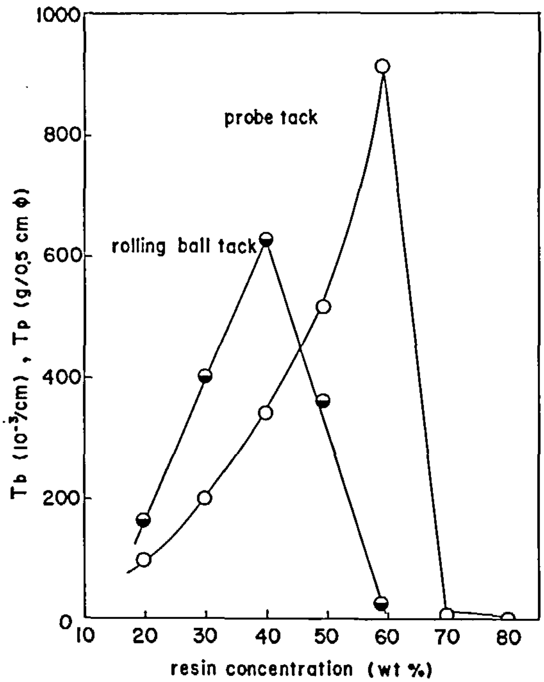

Figure 12. Dependence of rolling tack (Tb) and probe tack (Tp) on the resin concentration.

3.5 Tack Map

The results of four different tack tests and two finger tests on four different commercial cloth adhesive tapes are summarized in the map shown in Fig. 13. The broken center line in the map indicates the average value of measured values for each test method. The vertical line indicates the difference between the measured value and the average values. Direct comparison of the measured values obtained by each test method is not possible, but one can compare the sequence of the measured values for each sample obtained by each test method.

In this map, finger test (1) shows the results obtained from the finger tests by the use of the universal tensile tester shown in Fig. 5 and finger test (2) shows the results obtained from the test by the feeling of a thumb. It is seen from the map that the results obtained from the rolling ball tack test, the finger test (1) and the finger test (2) agree quite well. Matsumoto et al.[10] adhered an adhesive tape on the uneven surface of a Bakelite plate and determined the distribution chart of stress produced during the detachment of the adhesive tape, hoping that the finger test could be carried out more objectively. As has been pointed out by J. Dow,[6] the rolling ball tack test is the simplest test method which can give test results almost identical to those obtained from the finger test.

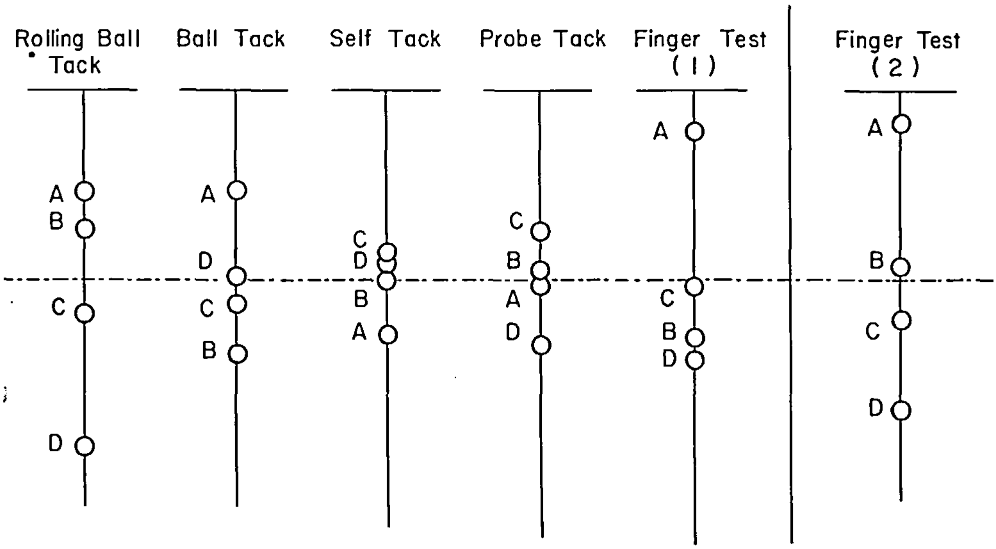

Figure 13. Tack map of cloth adhesive tapes.

4. SUMMARY

Tackiness of commercial adhesive tapes was determined by the use of several test methods. It is found that the results obtained from the rolling ball tack tester with a curved surface which can be represented by the sine curve of $y = 86.7 \cos(\pi/300 \times x) + 86.7$ are closest to those obtained from the finger test. (Presented at 6th Symposium for Adhesive Research, June 6, 1968).

REFERENCES

1. F. H. Wetzel, *ASTM Bulletin No. 221,* 64 (1957).
2. Kobe and Kamagata, *J. Adhesion Soc. of Japan* **4,** No. 4,224 (1968). H. Kambe and K. Kamagata, *J. Appl. Polymer Sci.* **13,** 493 (1969).
3. F. H. Hammond, Jr., *ASTM Bulletin No. 360,* 123 (1965).
4. N. Brunt, *Rheol. Acta* **1,** 242 (1958).
5. Toyama, *Kobunshi* **17,** No. 201, 1248 (1968).
6. J. Dow, *Proc. Inst. Rubber Ind.* **1,** 105 (1954).
7. Test Methods for Pressure Sensitive Tapes PSTC-18 (The Specification and Technical Committee of PSTC).
8. C. W. Hock, *J. Polymer Sci.* **C3,** 139 (1963).
9. Fukusawa and Kosaka, *J. Adhesion Soc. of Japan* **3,** No. 1, 1 (1967).
10. Matsumoto, Nakamae, Doi and Kinoshita, Abstract of the 6th Symposium of Adhesive Research, p. 59 (1968).